



R.C.A. INSTITUTES

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Technical Lesson 18

METERS

If you were a steam engineer you would not think of working near boilers which had not been equipped with steam gauges to indicate the amount of steam pressure. An instrument to show the pressure of the steam is quite necessary. Neither should you undertake electrical work of any importance without indicating instruments (meters) designed to measure electricity in the circuits which you may work with.

Of the different electrical indicating instruments, called meters, the first one to be considered in this lesson is one which may be employed to detect minute electrical forces. This is the ordinary magnetized needle and is one of the simplest forms of current detecting instruments.

The magnetized needle, when brought near a current carrying conductor, will indicate the presence of current in that conductor by being deflected. The needle will, if allowed to come to rest, take up a definite position relative to the direction of current passing through the conductor.

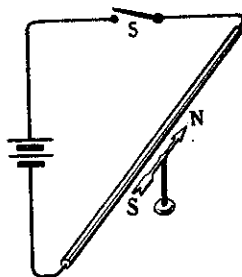


Figure 1

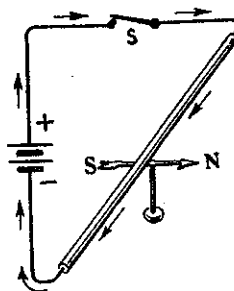


Figure 2

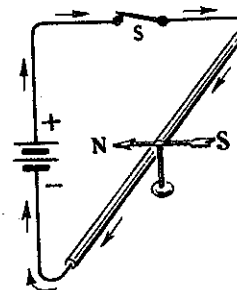


Figure 3

The following are experiments you may try with an ordinary magnetic compass, a length of wire, and dry cells. The compass is contained in a small metal case and covered with glass to protect the needle. Only the needle and support is shown in the figure.

In Figure 1 place a compass under a length of wire allowing the needle to come to rest, pointing to the North. Adjust the wire so that it is directly above and parallel with the compass needle. You will notice that the needle remains at rest, but when the switch "S" is closed the needle is deflected at once and will assume the position as shown in Figure 2. Change the position of the wire by placing it underneath the needle and the needle will point in the opposite direction and the deflection of the needle will then be as shown in Figure 3.

Next form a closed loop of the wire as shown in Figure 4 and place the needle in the center of the loop midway between the top and bottom wires. In this position the needle will not show any deflection when the switch is closed, providing the current strength is equally divided in both sides of the conductor forming the closed loop.

When the compass is placed closer to one or the other of the two conductors, one above and the other below the compass, the needle will be influenced by the conductor nearest to it. Or if the wires are of unequal resistance and more current flows in one than the other the needle will be influenced by the wire carrying the greatest current. Carry out further experiments with circuits as shown in Figures 5 and 6 and make notes as to the resulting deflection of the compass needle. You may originate any experiment you desire, watching carefully the polarity, but keep the switch closed only momentarily if a short wire is used. Increase and decrease the current flowing in the conductor and carefully watch the movement of the compass needle when held at various distances from the conductor.

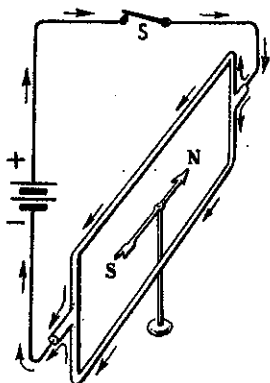


Figure 4

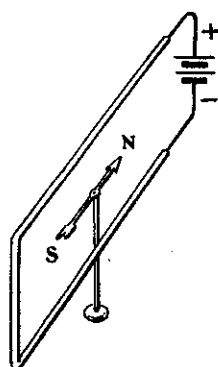


Figure 5

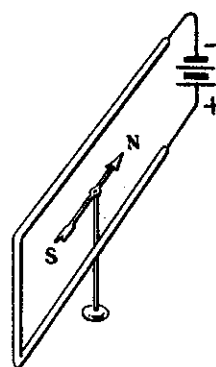


Figure 6

The value of the compass as an electrical indicating instrument lies in its ability to detect the presence of current and, by the deflection of the needle, polarity may be determined.

THE GALVANOMETER

The galvanometer is designed to detect small currents of electricity and to measure their relative strength. Two types used in research laboratories are the Thompson Astatic, and D'Arsonval galvanometers. These instruments operate under different principles and have their particular values for certain kinds of work.

The Thompson Astatic galvanometer derives its name from the position of two sets of permanent magnets which are secured to mica discs and joined together by a stiff wire so that their poles are reversed, thus neutralizing the magnetic influence of each other, in other words, they are in astatic relation to each other. About each set of magnets is a coil of wire wound in a direction which, when current is passed through

the coils, the influence of the resulting field will tend to turn the magnets in the same direction. The astatic position of the magnets in neutralizing each other eliminates the effect which the Earth's magnetic field would otherwise exert upon the system. A light mirror is secured to the wire joining the two sets of magnets on which a beam of light is directed. With this delicate system very minute currents can be detected by the movement of a mirror which is deflected as current passes through the coils. Figure 7 illustrates a fundamental plan of this instrument. As the revolving element of this meter is suspended by a cocoon fibre it turns very easily and will swing back and forth for some time after being set in motion. The mica discs, however, tend to stop this swinging movement to a certain extent, thus tending to make it dead beat. (Dead beat meaning to stop swinging when current through the coils becomes constant.)

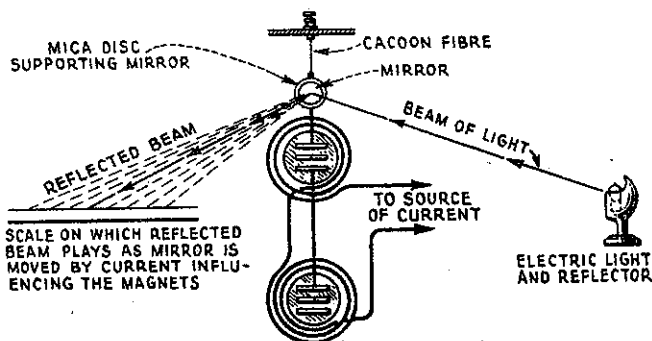


Figure 7

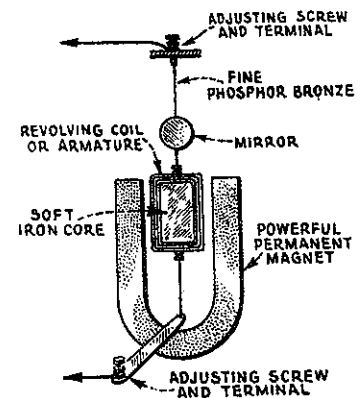


Figure 7A

THE D'ARSONVAL GALVANOMETER

In the type of indicating instrument just discussed we have concerned ourselves with the type of galvanometer in which the magnet formed the moving elements. We now find in the D'Arsonval galvanometer a type in which the magnets are stationary and a coil of wire forms the moving element. Figure 7A.

The wire forming the armature is wound on a rectangular frame in the center of which is placed a soft iron core. This core serves to concentrate the powerful field of the permanent magnets in which it is suspended. Both the wire frame and core are supported by a fine phosphor bronze wire at top and bottom through which the current passes in reaching and leaving the winding of the coil. When current is passed through the instrument it sets up a field about the coil producing a North and South pole and, since it is suspended in the powerful magnetic field of the magnets, the North pole of the armature coil tends to turn toward the South pole of the magnet and the South pole toward the North pole of the magnet.

In the laboratory type a mirror is moved when current passes through the coil and, if a light beam is directed on the mirror, this beam will be reflected along a scale. By winding the coil on a non-magnetic core the instrument becomes practically dead beat, for as soon as the coil moves in the field of the permanent magnets induced currents are set up in this non-magnetic frame which are in such a direction that they tend to stop the motion producing them (Lenz's Law).

An instrument of this kind, with proper design, may be equipped with a pointer and used commercially. For example, the Westinghouse P X 2 type galvanometer, shown in Figure 8, has an extremely sensitive D'Arsonval movement, the coil being supported by fine pivot bearing accurately fitted in sapphires which make it suitable for precision measurements and laboratory work. This instrument may be used in radio circuits, for example, to measure B power unit voltages when the potentiometer method, as shown diagrammatically in Figure 9, is used. This meter can then be used to obtain correct readings of B voltages with an ordinary low resistance voltmeter. The readings thus obtained will be true voltages because this method does not increase the load which would cause a corresponding voltage drop on the B battery power unit, as in the ordinary voltmeter test.



Figure 8

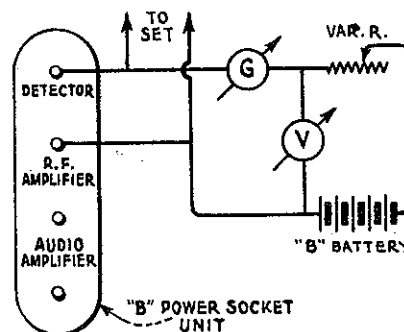


Figure 9

The galvanometer is very useful and has many applications but from the very nature of the construction of such instruments it is obvious that a current of any considerable magnitude could not be passed directly through the windings because of their low resistance. There is, however, a method we can incorporate which permits us to connect a delicate galvanometer in circuits carrying hundreds of amperes and that is by connecting in the meter circuit a special resistance alloy, called a shunt.

THE SHUNT

For many years it was necessary, when stating the resistance of a metallic substance, to qualify the statement by adding that the resistance would be a certain value at a certain temperature, that is, as the temperature of a metal increases so does its resistance. This peculiarity was more pronounced in some metals than in others and when resistance was used its temperature had to be first determined before a positive statement could be made relative to its true resistance.

Dr. Weston of the Weston Electrical Instrument Company, after many years of research, succeeded in producing a metallic alloy the resistance of which actually decreased as its temperature increased. This was exactly what was required in the manufacture of shunts used with measuring instruments and it insured great accuracy in the reading of electrical meters.

If an ammeter is placed directly in the line as shown at A, Figure 10, the only path for the current is directly through the instrument. Suppose the instrument was designed for a current of 1 ampere and the line was carrying 50 amperes, - the meter certainly would be destroyed. To understand the principle of the shunt refer to B, Figure 10. The resistor "R", which has been added, is adjusted until it is the same as the resistance of the meter windings and, when the current is thrown on, half the current will pass through the meter direct and half through the resistor or shunt and, to obtain the correct reading in amperes, we multiply the reading of the instrument by 2. If now we add another shunt of the same resistance as in "C", Figure 10, two thirds of the total current will pass through the shunt and one third through the meter. This ratio may be carried on indefinitely, and by employing the proper shunt value of resistance, a very delicate and low resistance meter may be used to measure very high current values. When we consider the resistance of the shunt required it is not necessary to have a number of individual shunts because they can all be made into one piece of resistance alloy.

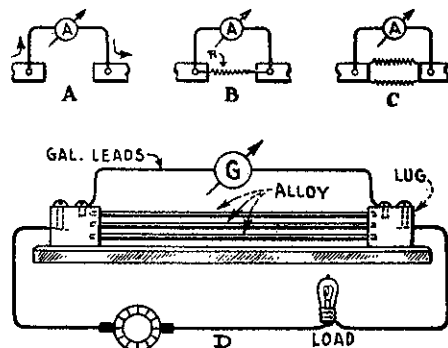


Figure 10

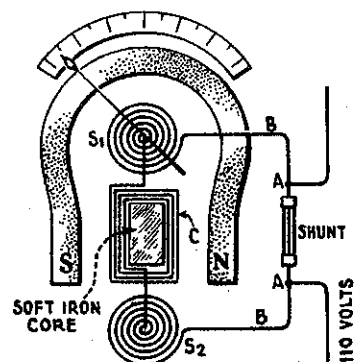


Figure 11

A form of commercial shunt is shown at D, Figure 10. The alloy strips are soldered into lugs and spaced for ventilation. The measuring instrument is then connected to the lugs.

THE AMMETER

Since, by the foregoing method, the current flowing in the coils of the galvanometer can be divided and proportioned we can now utilize the galvanometer in different ways for practical purposes. When a shunt is placed across the terminals of a galvanometer we then have an ammeter. The ammeter is calibrated so that the needle, in moving

over the scale, reads directly in amperes. These instruments are in fact merely portable types of D'Arsonval galvanometers. Up to a certain current value, (approximately 30 amperes) the shunt is placed inside the case containing the working part of the ammeter and is generally in the form of high resistance wire. When larger currents are to be handled the shunt takes the form as shown in Figure 10D and is connected to the terminals of the ammeter, but outside of the case of the instrument marked G.

A fundamental drawing of the Weston ammeter appears in Figure 11. AA are binding posts by which the instrument may be connected to the source of current and across which is connected the shunt. The wires BB, connect to the springs S₁ and S₂ and carry the current to and away from the armature. The armature is rectangular in shape and wound on a non-magnetic metal frame. Between the North and South poles of the permanent horse shoe magnet is a soft iron cylinder core which is stationary and placed there to improve the magnetic circuit of the magnet thus producing a more uniform field in which the coil moves. The coil swings between this soft iron core and the permanent magnet pole pieces when current is flowing. As current is passed through the armature winding the lines of force between the normal field from N to S of the horse shoe magnet are lengthened out and, in trying to shorten themselves, they actually twist or turn the coil.

When the tension of the springs, S₁ and S₂, is equal to the pull of the magnetic field the pointer, which is attached to the armature coil frame, comes to rest and the reading of the instrument may be taken from the scale over which the pointer swings.

The wire used in the armature is very fine and is designed to carry only a small fraction of the total current flowing, therefore, to make the instrument capable of measuring large current values the shunt must be placed across the armature coil.

USE OF THE AMMETER

Ammeters are found in all phases of electrical work and are designed to measure minute currents of a few thousandths of an ampere as well as currents of thousands of amperes. In radio work the ammeter is used to measure the current in different parts of the circuit such as for determining the current in the filament and plate circuits. When used in the plate circuit they indicate the current in milli-amperes and are therefore called milliammeters. (milli meaning a thousandth part.)

The ammeter must always be connected in series with the line hence, when connecting an ammeter in a circuit, it is necessary to open one side of the line and connect the ammeter in such a manner that the current flows through it. Care must be exercised in making certain that the instrument will have a range sufficiently great enough to carry the current flowing.

Figure 12 illustrates the connections for measuring the B battery current using a direct current milliammeter. The current of the filament circuits, ("A" battery current), may be measured by following the diagram shown in Figure 13.

The student must thoroughly understand that the ammeter must always be connected in series with the circuit. NEVER CONNECT AN AMMETER ACROSS THE LINE.

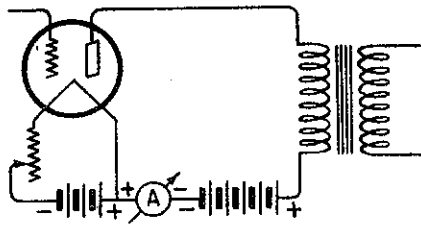


Figure 12

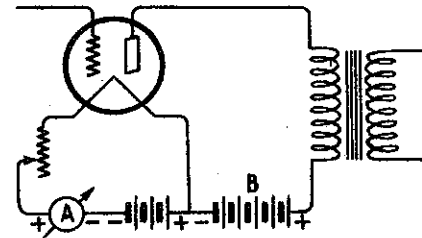


Figure 13

THE VOLTMETER

Any galvanometer in which a high resistance coil is part of the movable armature coil circuit may be employed to measure the voltage of an electrical circuit.

A voltmeter is simply a galvanometer in which a coil of high resistance has been connected in series with the moving coil, or included in series with the circuit.

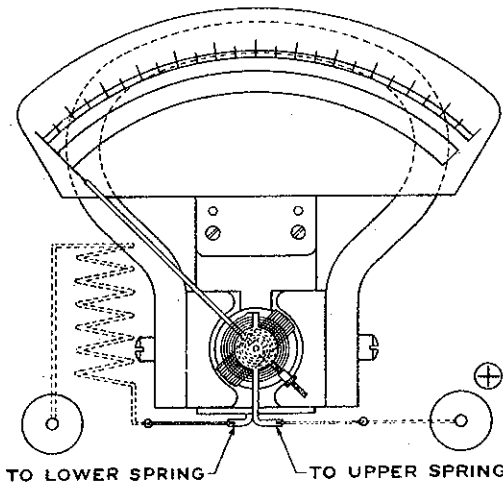


Figure 14

Figure 14 shows a plan diagram of a typical Weston direct current movable coil voltmeter which consists essentially of a light rectangular coil of copper wire usually wound upon an aluminum frame, pivoted in jeweled bearings, and mounted to rotate in an annular space between the soft iron core and the specially formed pole pieces of a permanent magnet. A light tubular pointer is rigidly attached to the coil and moves over a calibrated scale.

The current is lead into and from the coil by means of two spiral springs, which serve also to control its movements. This movement is due to the dynamic action between the current flowing through the coil and the

magnetic field of the permanent magnet. The pointer becomes stationary and the coil attains a position of equilibrium when the opposing forces of the springs equal the force caused by the rotary tendency of the coil. Since the magnetic field is uniform and the torsion of the springs proportional to the deflection, the scale divisions are

practically uniform. The higher the resistance of the windings the more sensitive the instrument because of the fact that the current flow in a high resistance is very small and does not appreciably affect the voltage to be measured.

Voltmeters must be placed across the line as shown in Figure 15. Here we illustrate the method of measuring the voltage applied to the filament of a vacuum tube.

A.C. METERS

The meters thus far discussed have been the magnetic type which are employed in direct current circuits. These types of meters will not function when connected to an alternating current circuit because of the fact that one alternation would tend to move the coil in one direction and the following alternation would tend to move it in the opposite direction. These alternations occur so rapidly that the moving element, in tending to obey one impulse, is almost immediately caused to move in the opposite direction by the succeeding impulse with the result that the indicating needle remains practically stationary.

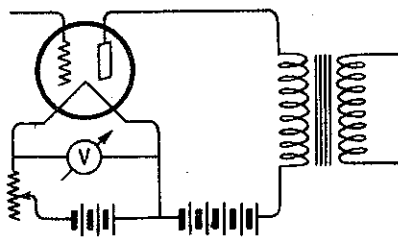


Figure 15

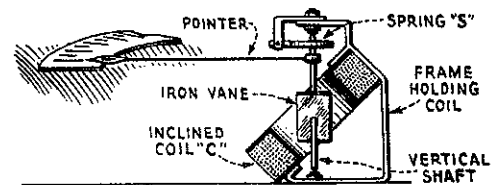


Figure 16

THE THOMPSON A.C. METER

The Thompson inclined coil meter, manufactured by the General Electric Company was developed to measure alternating current. The working parts of the instrument are shown in Figure 16. The inclined coil C, through which the current passes, is shown in cross section. It is mounted with its axis inclined to horizontal. In the center of this coil is placed a vertical shaft mounted in jewel bearings and controlled by a fine flat hair spring "S". At the center of this shaft a vane of soft iron is obliquely mounted.

When no current is passing through the coil "C" the pointer rests at the zero position, held there by the spring "S", and the iron vane lies nearly across the axis of the coil. When current is passed through the coil the iron tends to turn in such a position that the lines of force passing through it will be parallel to the lines of force in the coil. The pointer which is attached to the top of the vertical shaft then swings over the graduated scale from which the reading is obtained.

WESTON A.C. METERS

The armature coil of these instruments is wound with a few turns of heavy wire when the instrument is to be used as an ammeter and, when employed as a voltmeter, a large number of turns of fine wire are wound on the coil, and, connected in series with this coil, is an accurately adjusted high resistance coil. The moving armature, which lies in the center of the coil, consists of a small piece of soft iron, semi-circular in shape, secured to a vertical shaft which is pivoted at

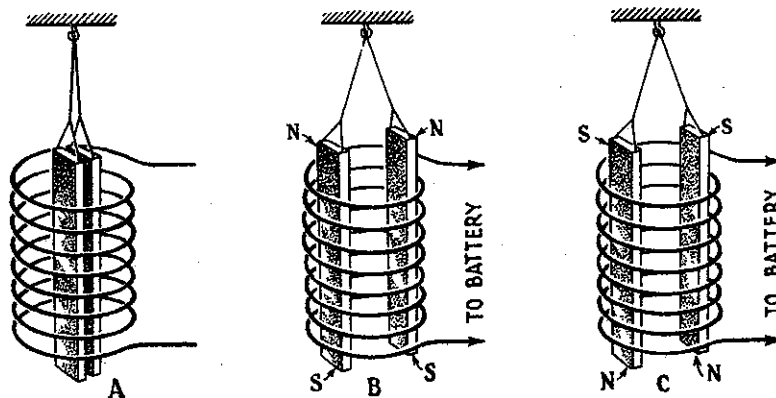


Figure 17

both ends and accurately fitted in jewel bearings. A pointer of truss construction and very light in weight is secured to the upper end of the shaft. A small vane is attached to the pointer which moves in a small air compartment. This vane, as it moves in the closed air compartment, provides the damping required to prevent the pointer from oscillating, thus making the instrument "dead beat". To accurately balance the pointer in the bearings the non-indicating end of the pointer which crosses the shaft, is threaded and provided with a

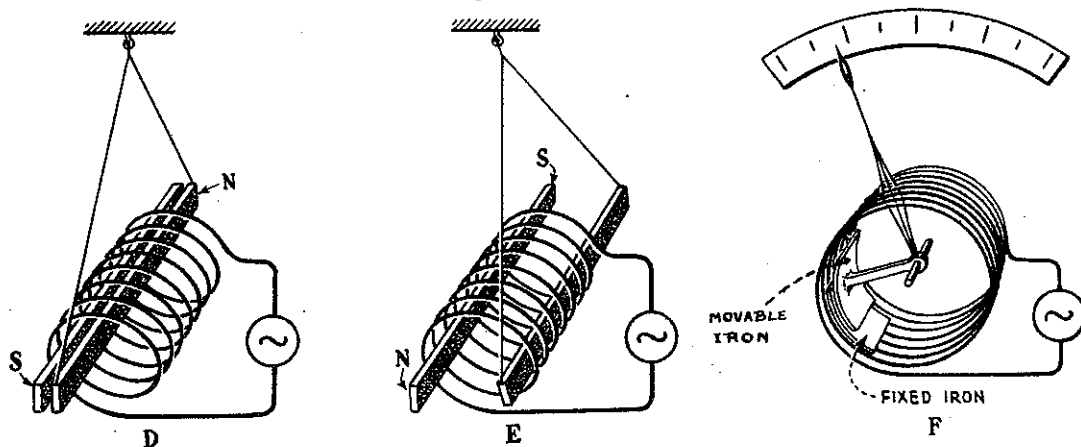


Figure 17

small weight which may be run forward or backward until a balance is obtained. Situated close to this movable iron sleeve is secured a fixed piece of curved iron, triangular in shape, with the small end of the triangle rounded off. This piece of iron is securely held in place,

does not move, and has no physical connection to the armature circuit. When current is passed through the fixed coil a magnetic field is set up which magnetizes the fixed triangular piece of iron and the curved movable iron elements due to induction. As both the fixed iron and the iron of the movable element are within the field coil their adjacent ends will develop like polarities and, since they are alike as to polarity, repulsion takes place between them. The only motion possible, due to the repelling action between the two pieces of iron, is the movable element which tends to move away from the like pole of the fixed iron sleeve. The pointer therefore, swings over the scale as it is attached to the movable element.

The motion of the pointer is controlled by the spiral spring at the top of the shaft, which opposes its motion, and when current ceases to pass in the coil the pointer returns to zero position. The pointer swings over the scale and comes to rest at once due to the damping vane attached to the pointer and which moves in the closed air compartment.

The plan of the A.C. meter is shown in Figure 17. "A" is an insulated coil of wire in the center of which is suspended two pieces of soft iron. When no current is flowing through the coil the iron strips will remain as shown. When, however, a battery is connected so that direct current flows through the turns of the coil in such a direction that the iron strips are magnetized and develop N poles at their upper ends and S poles at their lower ends, we have two magnets having like poles and, since like poles repel each other, the two iron strips will be forced apart as shown at B. If the direction of the current flowing through the coil is reversed by reversing the connections to the battery the iron strips are again magnetized but this time develop S poles at their upper ends and N poles at their lower ends. If some means can be provided whereby the current passing through the coil can be rapidly reversed these two iron strips will continually develop polarities which will tend to produce a continual opposition between them thus keeping them constantly apart as long as current is flowing. This is done when the coil is connected in an alternating current circuit.

Suppose we go a step further and fasten one of these iron strips to the side of the coil in a manner that will prevent it from moving and then suspend the remaining iron strip as shown at D. By applying alternating current to the coil at D the suspended strip will be forced away from the fixed piece of iron as shown at E.

One more step;- this time we will secure a fixed iron plate as shown at F and suspend the other plate by a set of bearings which will compel the suspended strip to move only by rotation. Now, by applying alternating current to the arrangement at F, the suspended plate will be forced away as before and, as it moves, it will describe an arc. To this movable plate we have secured a light pointer which moves over a graduated scale and indicates the current passing through the coil.

Figure 18 is a cutaway photograph showing the fixed and movable iron sleeves or plates in place inside the windings of an A.C. voltmeter and an A.C. ammeter, and a view of the damping compartment from which the cover has been removed.

THE WATTMETER

The power in watts in a direct current circuit is equal to the volts multiplied by the amperes. By connecting an ammeter and voltmeter in a D.C. circuit, as shown in Figure 19, the value of current and voltage may be read. The ammeter reads 3 amperes and the voltmeter 2 volts; by multiplying these two values we can find the power in watts, thus $2 \times 3 = 6$ watts.

The wattmeter, which is really two instruments in one, a voltmeter and an ammeter, performs this computation for us automatically giving a

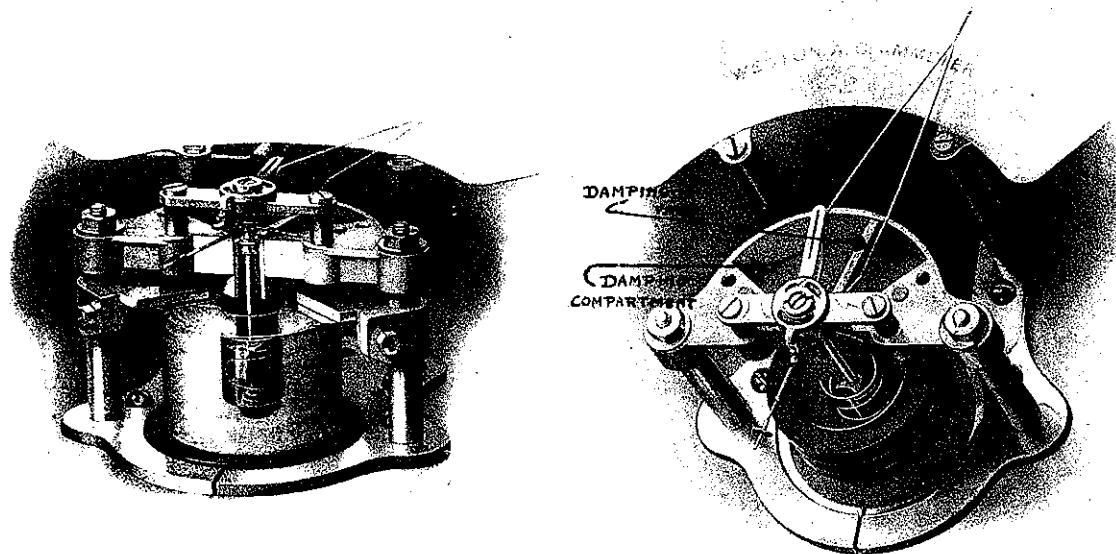


Figure 18

reading directly in watts. Two coils are used in this instrument, one is called the voltage coil and the other the current coil. The current coil is fixed and is connected in series with one side of the line just as you would connect an ammeter. The voltage coil is the movable element and is connected across the circuit just as you would connect a voltmeter.

A fundamental diagram of a wattmeter appears in Figure 20. The coils CC are wound with heavy wire which will permit the total current to flow through them without becoming excessively heated. The ends of these coils are brought out to two heavy binding posts shown in the diagram as BB. The movable coil D is the voltage coil and is connected across the line through the high resistance coil R and small binding posts at E. The winding on the coil D consists of a few turns

of fine insulated wire, the entire coil being placed on a light vertical shaft which is mounted in jewel bearings. Near the top of the shaft is secured the pointer P and balanced cross X; each end of the cross X is threaded and fitted with small balancing nuts. The non-indicating end of the pointer is threaded and fitted with a balancing nut or weight in the same way. Immediately below the cross is secured the controlling springs Y which forms the terminals to the voltage coil.

The magnetic force acting on the movable coil D depends upon the current flow in each coil. In the voltage coil the current will vary as the potential difference between its terminals vary, and the current through the coils CC will vary directly as the current varies in the circuit to which it is connected. The forces of the two coils set the movable coil in motion and, as it turns against the torsion of the springs, the pointer P swings over the scale S which is graduated in watts. This instrument may be used on either alternating or direct current circuits. Care, however, must be taken to see that the instrument is not connected in a circuit carrying a current value above its rating.

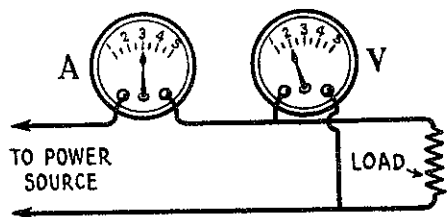


Figure 19

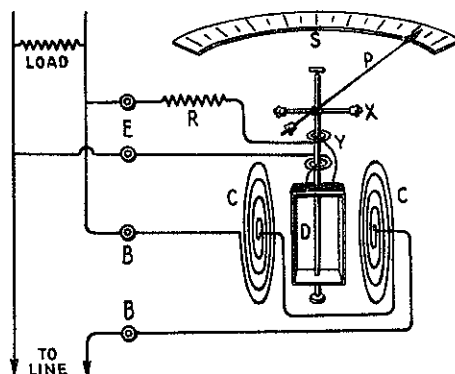


Figure 20

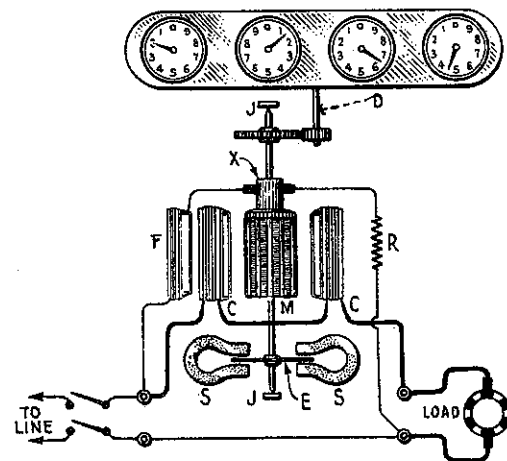


Figure 21

WATT HOUR METER

The power in watts of a circuit is the product of the volts times the amperes. In a D.C. circuit there is no "power factor" whereas, in A.C. circuits, the "power factor" must be considered. In alternating current circuits power is equal to the voltage times the current, times the cosine of the angle of lag or lead. This formula for power is expressed, $P = I \times E \times \cos \phi$.

In the watt hour meter the power factor is automatically taken care of in the calibration of the instrument and the watt hours are read directly from a set of dials.

A simple diagram of the Thompson Wattmeter is shown in Figure 21. It's construction and design is similar to the wattmeter just described with the exception of the moving element. This element is a small motor which revolves between the two large field or current coils CC. The shaft supporting the armature of the motor is mounted in jewel bearings. Instead of a pointer at the top of the shaft a set of gear teeth is arranged which turns a shaft D, mechanically and automatically counting the total number of kilowatts of energy consumed per hour. Since this meter records the total number of kilowatt hours it is called an intergrating watt hour meter. The magnetic forces of the coils M and CC causes the armature coil M to revolve and the rate of rotation will be proportional to these two magnetic effects.

The light aluminum disc E which is attached to the lower end of the armature shaft revolves with the shaft and passes between two strong permanent horse shoe magnets SS. As this disc turns, electric currents (eddy currents) are set up in it by the magnetic field of the magnets, and these currents when set up produce a retarding effect which tends to prevent the motion producing them. This disc then, is in effect, a brake which prevents the armature coil from running away. It also stops the armature as soon as current flow is discontinued.

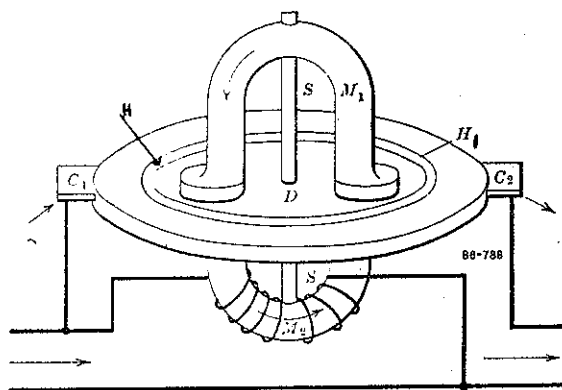


Figure 22

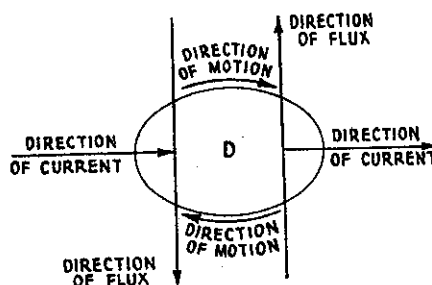


Figure 22A

To compensate for the small amount of friction present at the jeweled bearings JJ, and commutator X, a small compensating field coil F is connected in the shunt circuit of the armature, as is the high resistance R. This meter may be used on either alternating or direct current circuits.

THE SANGAMO D.C. WATTMETER

The sangamo watt hour meter has a copper disc as its armature instead of the coil of wire and commutator. The copper disc is inclosed in a mercury chamber in which it revolves, the mercury forming part of the circuit. This design practically eliminates commutator friction as the disc floats in the mercury. The sangamo meter, which is a mercury motor, consists essentially of the copper disc which floats in the mercury and which lays in the field of an electromagnet. Leads are provided to direct the current to and from the mercury at diametrically opposite points.

The relations of the various parts are shown in Figure 22. The current of electricity carried by the circuit in which energy is to be measured enters at contact bar C1, passes through the comparatively high resistance mercury H, to the edge of the copper disc D, crosses the disc to the mercury H1, and out at contact bar C2.

A magnetic field which cuts the copper disc and which consequently produces rotation when current passes through the disc is obtained from the electro-magnet M2 which is energized by the windings shown connected across the line. A soft steel plate is placed above the mercury chamber shown in the diagram as M1; this acts as a return for the magnetic lines of force from the electromagnet M2.

According to the laws of electromagnetic induction, if a current carrying conductor cuts a magnetic field at right angles, a force is exerted upon the conductor tending to push it at right angles to both the current and the flux, hence the disc revolves at a uniform rate. The relative direction of the magnetic flux and the current of electricity as well as the resulting motion is shown in Figure 22A. Since the disc D is free to move and is carrying a current, the direction of which is at right angles to the fixed magnetic field produced by the magnets explained in Figure 22, the disc D is pushed by this magnetic force and moves from its initial position. This allows current to enter the disc at a different point on the edge of the disc D and it is again pushed out of the field.

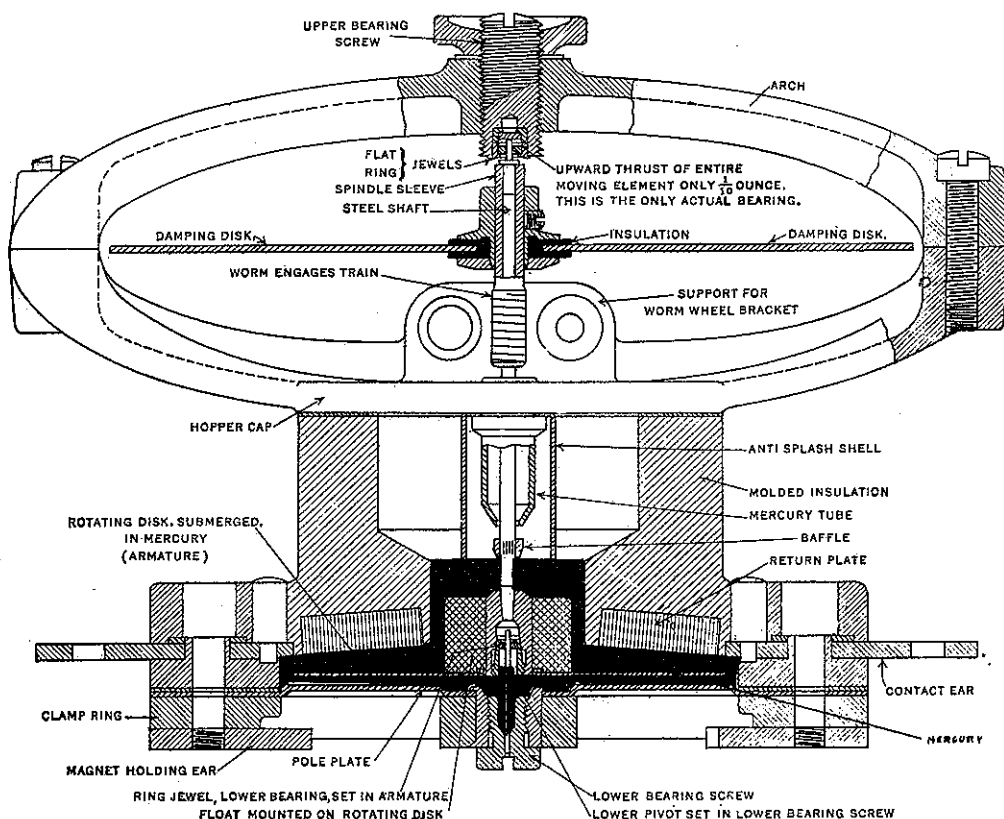


Figure 23

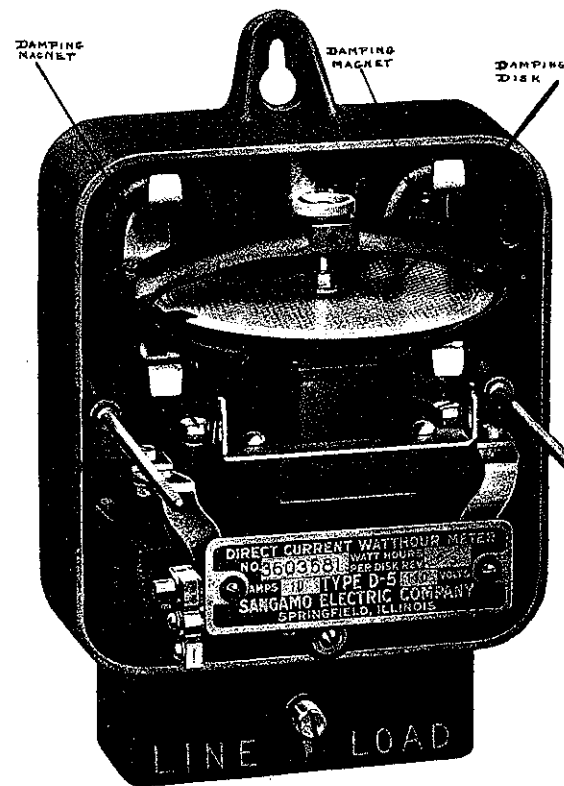


Figure 23A

With a constant change in the point at which current enters and leaves the disc rotation results, which continues as long as current flows in the circuit.

Figure 23 shows a cross section of this instrument which the student should study. Figure 23A is a view of the watt meter showing damping disc and damping magnets in place.

SANGAMO AMPERE HOUR METER

This meter is the type used on board ship in auxiliary battery installations. It not only indicates the state of charge of the battery but also automatically terminates the charge when the battery is fully charged. This meter, known as the N type, employs two permanent magnets which furnish the driving flux, damping, and retarding force. The shape and size of the magnets are such as to allow a very high state of magnetization.

By design, the poles of the steel plate and electromagnet are close together, being located directly above and below the disc, which

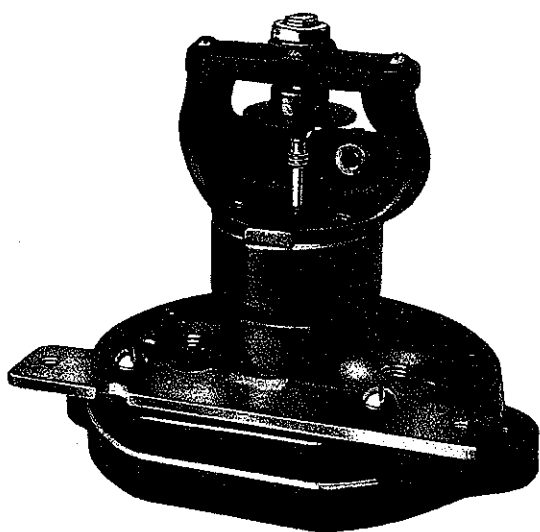


Figure 24

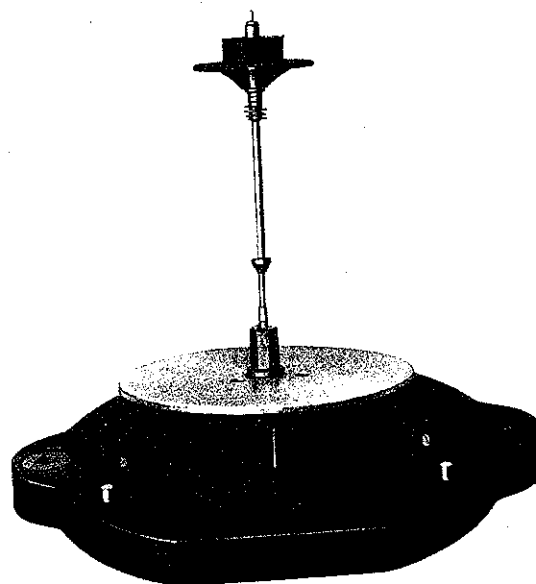


Figure 25

produces very dense and powerful fields across the disc. The armature chamber, a round flat box of moulded insulation, shown in Figure 24, contains the copper disc.

The fundamental operating theory is the same in this type as in the watt hour meter previously described. The moving element of the meter is shown in Figure 25. It comprises a solid copper disc and a hardened shaft securely fixed in the main hub. The upper end of the shaft carries the worm and the highly polished pivot. Over the worm is fitted the counter weight which regulates the flotation of the moving system so that the upward pressure of the pivot against the jewel bearing is about one tenth of an ounce.

Storage batteries do not give as much energy as is put into them. A meter designed for use with storage batteries must, therefore, automatically provide for the required excess of charge or discharge. This compensating arrangement should be adjustable over a considerable range since it is a matter of common knowledge that batteries of different types, as well as batteries of the same type but in different classes of service, require different settings in order to give the amount of overcharge best suited to the particular conditions.

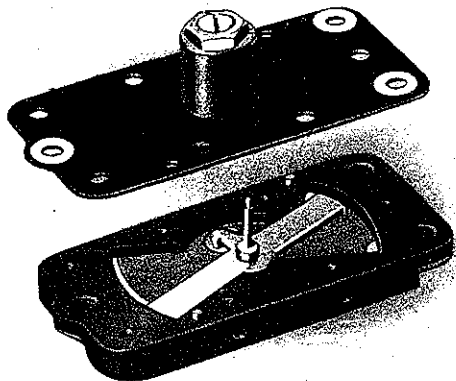


Figure 26

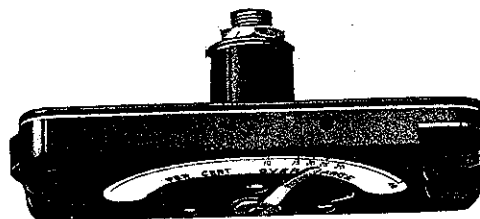


Figure 27

The sangamo meter is provided with a variable resistor element, Figure 26, which consists of a small auxiliary mercury chamber which is located in the leakage fields of the permanent magnets and equipped with a pivoted copper vane. This mercury chamber is connected in series with the armature circuit so that the pivoted copper vane tends to rotate according to the direction of current through the meter, operating on the same principle as the main disc. The movement of the resistor is limited to an angle of 45 degrees or less by a pin inserted in the ends of an eccentric screw.

On discharge the vane takes a position over a copper contact directly connected to the armature chamber thus providing a low resistance path to the main armature circuit and causing the meter to rotate at normal speed. On charge the vane swings away from this contact point thereby introducing resistance in the main armature circuit because the current to the armature chamber must now pass through mercury as well as copper. In this position more of the current is naturally shunted away from the armature circuit and the meter runs slower. The amount of swing of the vane away from the discharge position is regulated by means of an external pointer, Figure 27, which moves over an accurately calibrated scale, thus allowing the meter to be set for any overcharge from 0 to 40 percent. The resistor is constructed so that it carries the entire armature current thereby being very sensitive and positive in action.

Figure 28 shows the type N ampere hour battery meter with resistor in place. Figure 28A shows the permanent magnets and armature box. A cross section of the N type meter is illustrated in Figure 29.

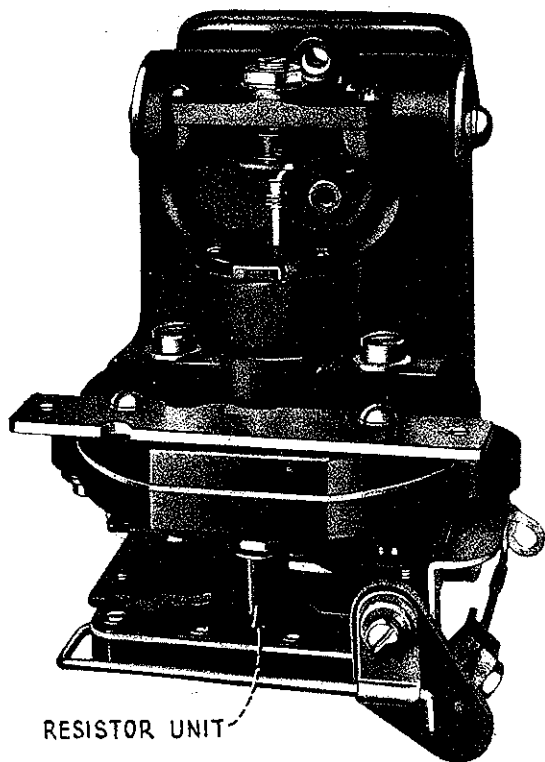


Figure 28

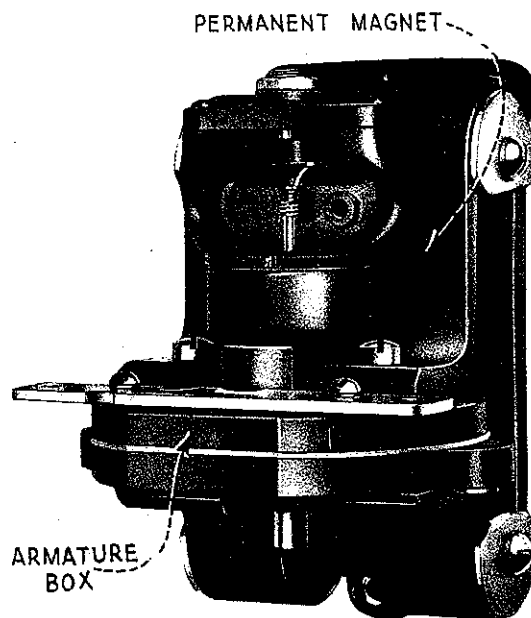


Figure 28A

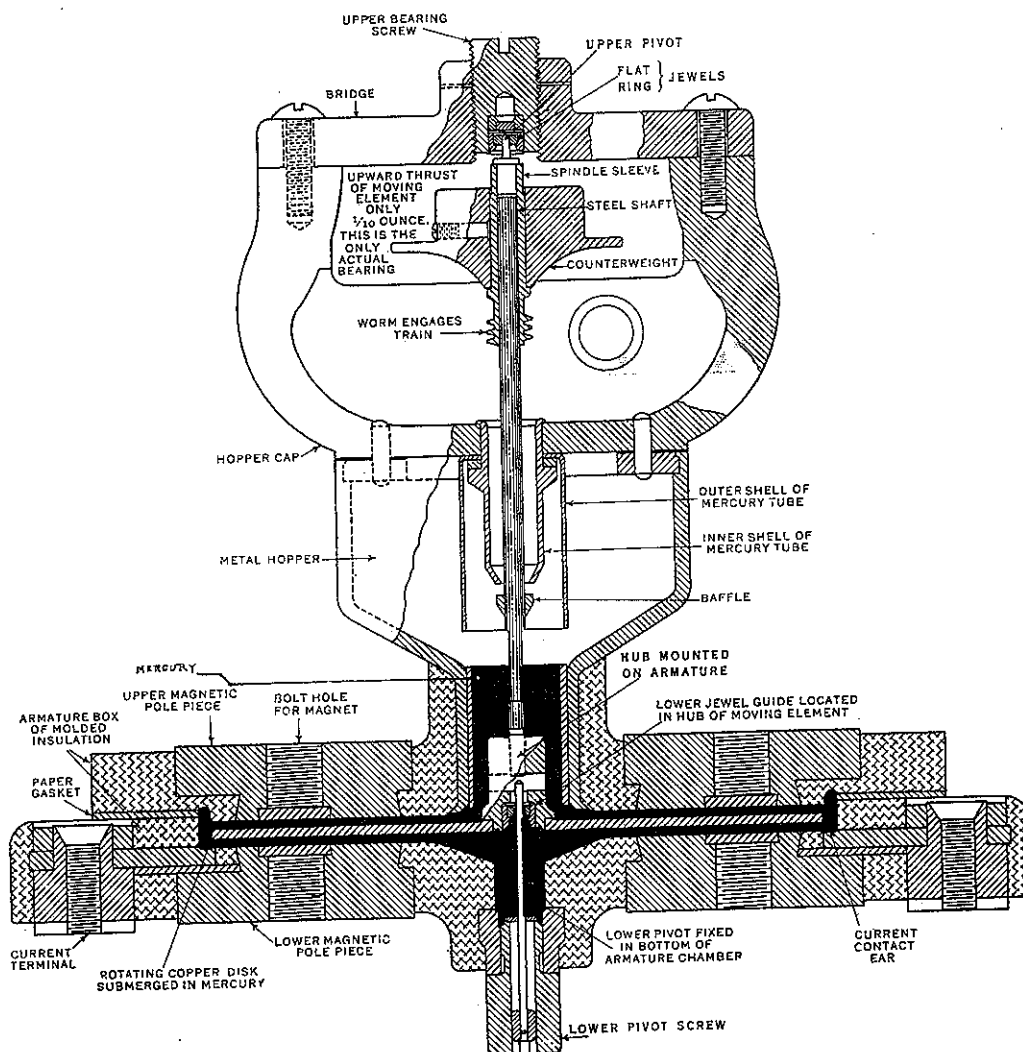


Figure 29

RADIO FREQUENCY METERS

The hot wire ammeter may be used to measure current in both A.C. and D.C. circuits, and it may also be employed to measure currents at radio frequency. The fundamental circuit of this meter is shown in Figure 30.

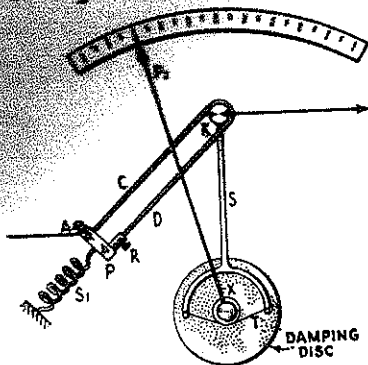


Figure 30

A steel plate P is made to pull against the wire CD by the spring S1. One end of the wire CD is attached to the plate P at A, passed around the pulley K, and is again attached to P at R, where it is insulated. The pulley K carries the arm S with two prongs between which is stretched a silk thread T wound about the shaft X. X carries the pointer P1 which moves over the scale. The current to be measured enters the wire at point A and leaves at the pulley K. As the current flows the temperature of the wire C is raised, causing it to expand but, owing to the tension of S1, the slack is taken up at the side and equilibrium can be restored only when the pulley K rotates sufficiently to equalize the pull on the spring. The rotation of K carries S with it, and S, in moving, causes the silk fiber to rotate the shaft which carries the indicating needle P1.

When large values of current are to be measured a shunt must be provided to sub-divide the current flow. An inductive shunt cannot be used as the impedance would vary with each change in frequency, hence hot wire meters are constructed after the design shown in Figure 31 where several resistance wires are stretched in parallel between the large copper blocks B and B'. The wire AB is attached to the wire CD to which a silk fiber thread is attached at point K and then wound about the shaft M in such a direction that it will work against the spring S which normally would cause the pointer to move to the full scale position. However, by means of the thread, it is held in the zero position. When current is flowing through CD it expands, releasing the pull of the thread and allowing the pointer to move across the scale, according to the expansion of the wire and tension of the spring.

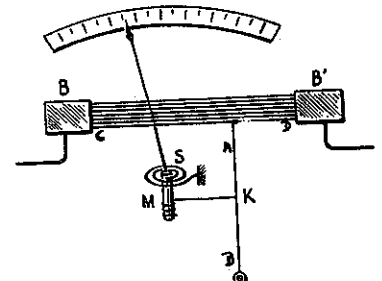


Figure 31

EXAMINATION - LESSON 18

1. Where is a shunt used to advantage with meters?
2. What instrument is used to measure radio frequency current?
3. Where would you employ an ampere-hour meter?
4. (a) What is a voltmeter? (b) Show how it is connected in a circuit.
5. Show how an ammeter is connected in a circuit.
6. What is a galvanometer?
7. Is there any type of meter which may be used to measure both D.C. and A.C.?
8. For what purpose is the wattmeter employed?
9. Is mercury a conductor of electricity?
10. Show a simple electric circuit with an ammeter and a voltmeter properly connected in that circuit.